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The Role of Lavender Essential Oils (LEO) in Managing Stress and Neuroinflammation: An Immunopsychiatric Perspective

Putri Faradisa Kamila[1], Hafid Algristian[2]
[12]Universitas Nahdlatul Ulama Surabaya, Indonesia
Correspondent: dr.hafid@unusa.ac.id[2]

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ABSTRACT: Lavender essential oil (LEO) has gained significant attention for its potential role in managing stress and neuroinflammation, offering a promising avenue in immunopsychiatry. Rich in bioactive compounds such as linalool and linalyl acetate, LEO exhibits anxiolytic, anti-inflammatory, and neuroprotective properties. Emerging evidence suggests that LEO modulates the hypothalamic-pituitary-adrenal (HPA) axis, reduces cortisol levels, and influences neurotransmitter pathways, thereby alleviating stress-related symptoms. Furthermore, its anti- inflammatory effects contribute to mitigating neuroinflammation, a key factor in mood disorders such as depression and anxiety. This review explores the immunopsychiatric mechanisms underlying LEO's therapeutic potential, highlighting its role as a complementary intervention in stress-related neuropsychiatric conditions.

Keywords: Lavender Essential Oil, Immunopsychiatric, Managing Stress and Neuroinflammation.

INTRODUCTION

Lavender essential oil (LEO) has gained attention for its potential therapeutic effects in managing stress and neuroinflammation. Derived from Lavandula angustifolia, LEO contains bioactive compounds such as linalool and linalyl acetate, which have been shown to exert anxiolytic and anti-inflammatory properties. In recent years, researchers have explored its impact on the central nervous system, particularly in the context of stress-related disorders and neuroimmune interactions.

Stress is a multifaceted physiological and psychological response to environmental challenges, often leading to dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis. Chronic stress has been linked to increased production of pro-inflammatory cytokines, contributing to neuroinflammation and exacerbating conditions such as anxiety and depression. Immunopsychiatry, an emerging field that examines the interplay between immune function and mental health, provides valuable insights into how LEO may mitigate stress-induced neuroinflammatory pathways.

LEO has been shown to modulate neurotransmitter systems, particularly gamma- aminobutyric acid (GABA), which plays a crucial role in reducing neuronal excitability and promoting relaxation.

Studies suggest that inhalation or topical application of LEO can enhance GABAergic activity, leading to anxiolytic effects. Additionally, the olfactory stimulation of LEO has been associated with decreased cortisol levels, further supporting its role in stress reduction. Muhammad et al. (2022)

Beyond its influence on neurotransmitters, LEO possesses significant anti-inflammatory properties. Research indicates that LEO can inhibit the release of pro-inflammatory cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), which are elevated during chronic stress and neuroinflammation. This suggests a potential role for LEO in mitigating neuroimmune responses that contribute to psychiatric disorders.

Preclinical studies have demonstrated that LEO may prevent stress-induced neurodegeneration by reducing oxidative stress and modulating microglial activation. Microglia, the resident immune cells of the brain, play a crucial role in neuroinflammation. Under chronic stress conditions, overactivated microglia can contribute to neuronal damage and exacerbate mood disorders. LEO has been found to suppress microglial activation, thereby protecting against neuroinflammatory damage.

Clinical trials examining the efficacy of LEO in stress and anxiety disorders have yielded promising results. For instance, randomized controlled trials (RCTs) have reported significant reductions in anxiety scores among participants exposed to LEO, whether through aromatherapy, massage, or oral supplementation. These findings underscore the therapeutic potential of LEO as a complementary approach to conventional psychiatric treatments.

Despite these benefits, further research is needed to establish standardized dosing regimens and long-term safety profiles of LEO. While generally considered safe, some individuals may experience allergic reactions or sensitivities to essential oils. Additionally, interactions with certain medications should be carefully evaluated to ensure the safe integration of LEO into therapeutic protocols.

From an immunopsychiatric standpoint, the ability of LEO to modulate both neurochemical and immune pathways highlights its potential as a holistic intervention for stress and neuroinflammation. Its natural origin and minimal side effects make it an appealing option for individuals seeking alternative stress management strategies.

In conclusion, LEO represents a promising natural therapeutic agent for managing stress and neuroinflammation. By influencing neurotransmitter activity, reducing pro-inflammatory cytokine levels, and mitigating microglial activation, LEO offers a multifaceted approach to mental health care. Further clinical investigations will be essential to fully elucidate its mechanisms and optimize its application in psychiatric and immunological contexts.

METHOD

This study adopted a systematic literature review approach to explore the role of lavender essential oil (LEO) in managing stress and neuroinflammation from an immunopsychiatric perspective Yoo

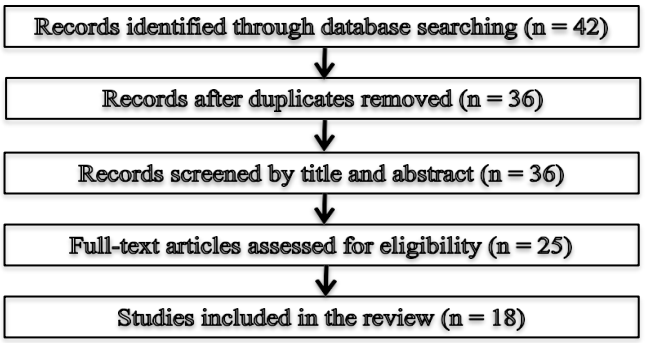
& Park (2023). The review was conducted by systematically searching peer-reviewed articles through scientific databases including PubMed, ScienceDirect, and Google Scholar.

A literature review is a research method that systematically analyzes existing academic sources, such as scientific journals, books, and other credible publications (Sugiyono, 2020). The literature search was performed using keywords such as "lavender essential oil," "stress," "neuroinflammation," "immunopsychiatry," and "mental health". Articles published between January 2013 and March 2024 were included to ensure relevance and the inclusion of recent evidence. DI (2019)

The following table summarizes the inclusion and exclusion criteria used for article selection:

Criteria	Inclusion	Exclusion
Type of Study	Clinical trials, preclinical studies, systematic reviews, meta-analyses	Opinion pieces, editorials, non-peer-reviewed articles
Language	English or Indonesian	Other languages without official translation
Focus Area	Studies examining LEO's Effects on stress, neuroinflammation, immune response	Studies unrelated to LEO or not discussing its role in stress/neuroinflammation
Full-text Access	Available in full-text format	Only abstract or incomplete data available

The inclusion criteria for this study focus on research discussing LEO's chemical composition, its impact on stress and the immune system, and empirical evidence from clinical and preclinical studies. Exclusion criteria include articles that are not directly related to the research topic or those with weak methodological validity (Sugiyono, 2020). A total of 18 scientific articles and books were collected based on searches conducted in the PubMed, ScienceDirect, and Google Scholar databases. These articles were selected through a title and abstract screening process according to predefined inclusion and exclusion criteria. All eligible articles were then fully reviewed and analyzed for inclusion in this study. The selection process is illustrated in the following PRISMA diagram:



Quality Assessment Methods

The selected studies were evaluated using a simplified quality appraisal checklist adapted from CASP tools. Criteria assessed included:

1. Study design and sample size,
2. Presence of control/placebo group,
3. Clarity of intervention details (dose, duration, method),
4. Measured outcomes (e.g., cytokine levels, cortisol, mood scales),
5. Reporting of limitations or side effects.

Only studies with moderate to high methodological quality were included. The data were analyzed thematically and categorized into three domains: pharmacological, psychological, and immunological aspects of LEO. The analysis aimed to identify patterns, mechanisms of action, and outcomes related to stress and neuroinflammation, as well as highlight knowledge gaps and limitations in current evidence.

RESULT AND DISCUSSION

Lavender essential oil (LEO) has been widely recognized for its calming and anxiolytic properties, making it a popular natural remedy for stress and anxiety. Recent studies suggest that LEO exerts its effects through multiple neurobiological pathways, including modulation of neurotransmitters, anti-inflammatory mechanisms, and antioxidative properties (Chrysargyris et al. (2016). These mechanisms position LEO as a promising complementary therapy for stress-related disorders and neuroinflammation, which are often linked to conditions such as depression and anxiety. Algristian, et al. (2022)

One of the primary mechanisms of LEO is its interaction with the central nervous system, particularly through the gamma-aminobutyric acid (GABA)ergic system. Linalool, a major component of LEO, has been shown to enhance GABAergic transmission, leading to reduced neuronal excitability and increased relaxation. Additionally, studies indicate that LEO may modulate

the hypothalamic-pituitary-adrenal (HPA) axis, helping to regulate cortisol levels and mitigate stress responses. These effects contribute to its potential in reducing anxiety and improving mood stability.

Beyond its role in stress management, LEO has demonstrated neuroprotective properties through its anti-inflammatory effects. Chronic stress and neuroinflammation are closely linked, with elevated levels of pro-inflammatory cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α) observed in individuals with mood disorders. LEO has been found to downregulate these cytokines, thereby reducing neuroinflammation and protecting neuronal integrity. This suggests that LEO could be beneficial in conditions where neuroinflammation plays a significant role, such as depression and neurodegenerative diseases.

In addition to its direct effects on the nervous system, LEO influences autonomic functions, promoting relaxation and reducing physiological markers of stress, such as heart rate and blood pressure. Aromatherapy studies have shown that inhalation of LEO can lead to significant decreases in sympathetic nervous system activity, further supporting its role in stress reduction. The integration of LEO in holistic therapeutic approaches, including aromatherapy and massage therapy, enhances its overall effectiveness in managing stress-related conditions.

Lavender essential oil (LEO) has been widely recognized for its therapeutic properties, particularly in managing stress and neuroinflammation. Research conducted by Eduardo Pereira de Azevedo et al. (2024) emphasizes the alternative therapeutic approaches for anxiety and depression, highlighting the role of essential oils, including lavender oil, in alleviating psychological distress. The calming effects of LEO have been attributed to its interaction with the central nervous system, specifically through modulation of gamma-aminobutyric acid (GABA) neurotransmission, which is critical for reducing excitatory signals in the brain. Additionally, studies have indicated that LEO exhibits neuroprotective effects by inhibiting pro-inflammatory cytokines, which play a significant role in neuroinflammation associated with chronic stress and anxiety disorders.

A systematic literature review with meta-analysis by Taslim NA et al. (2024) examined essential oil interventions for agitated behavior in dementia patients, further supporting the therapeutic benefits of LEO (Faisal et al. (2022). Their findings suggest that LEO has the potential to modulate behavioral disturbances through its anxiolytic properties, leading to improved quality of life in individuals suffering from neurodegenerative diseases. The study also underscores the immunopsychiatric perspective, where neuroinflammation is closely linked to psychiatric conditions, and suggests that LEO's anti-inflammatory mechanisms may contribute to its effectiveness in stress management.

The immunopsychiatric perspective on LEO's impact highlights its dual function in both mental health and immune regulation. Research by Vanessa Guimarães Alves Olher (2024) posits that LEO's bioactive compounds, such as linalool and linalyl acetate, exert anti-inflammatory effects by downregulating pro-inflammatory markers like interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α). These cytokines are often elevated in individuals experiencing chronic stress, indicating a

strong correlation between systemic inflammation and mental health disorders. Consequently, the administration of LEO may serve as a non-invasive intervention to mitigate neuroinflammation and enhance emotional well-being.

In addition to its neuroprotective and immunomodulatory properties, LEO has been shown to improve sleep quality, which is crucial for stress recovery. Vandresen et al. (2024) discuss how aromatherapy with LEO promotes relaxation by influencing the autonomic nervous system, leading to decreased cortisol levels and improved sleep latency. Poor sleep is a common consequence of stress and anxiety, and its persistence can exacerbate neuroinflammatory responses. By enhancing sleep architecture, LEO indirectly contributes to reducing neuroinflammation and stress-related disorders.

Further investigations into the mechanisms underlying LEO's therapeutic effects have pointed to its interaction with the hypothalamic-pituitary-adrenal (HPA) axis, which regulates stress responses. According to the study by Franciele Silva de Oliveira et al. (2024), LEO exposure can attenuate HPA axis hyperactivity, reducing cortisol secretion and thus preventing chronic stress-induced neuronal damage. This finding aligns with earlier research indicating that excessive cortisol levels can lead to hippocampal atrophy, which is associated with memory impairment and mood disorders. By modulating HPA axis function, LEO offers a potential pathway for stress resilience and neuroprotection.

Neuroinflammation, a contributing factor to various mental health conditions, is another critical area where LEO demonstrates therapeutic potential. The oil's anti-inflammatory properties, attributed to its complex chemical composition, including linalool and linalyl acetate, help mitigate this inflammation. Research indicates that these compounds possess antioxidant activities, further contributing to their neuroprotective effects. By reducing neuroinflammation, LEO may play a role in preventing or slowing neurodegenerative processes, offering a promising avenue for managing conditions associated with chronic inflammation in the brain. The connection between the gut brain axis, and LEO, is also showing to be a possible way to reduce neuroinflammation.

Neuroinflammation, a recognized catalyst in the pathogenesis of numerous mental health disorders, presents a critical therapeutic target where Lavender Essential Oil (LEO) exhibits significant promise. The oil's inherent anti-inflammatory capabilities, primarily attributed to its intricate chemical profile encompassing linalool and linalyl acetate, serve to effectively attenuate this inflammatory cascade. Contemporary research underscores that these compounds possess potent antioxidant activities, which synergistically bolster their neuroprotective effects. This multifaceted action involves modulating inflammatory signaling pathways, notably by inhibiting the production of pro-inflammatory cytokines and activating anti-inflammatory pathways. Consequently, LEO not only suppresses acute inflammatory responses but also holds the potential to intervene in chronic inflammatory processes underlying various neuropsychiatric conditions.

The LEO-mediated reduction of neuroinflammation is posited to play a pivotal role in the

prevention or deceleration of neurodegenerative processes. Conditions such as Alzheimer's disease, Parkinson's disease, and multiple sclerosis, often characterized by chronic cerebral inflammation, may derive substantial benefits from LEO intervention. In vitro and in vivo studies have demonstrated LEO's capacity to safeguard neurons from oxidative and inflammatory damage, enhance cellular survival, and support cognitive function. This neuroprotective efficacy extends beyond neurons, encompassing glial cells, which are integral in modulating cerebral inflammatory responses. Furthermore, LEO's modulation of microglia, the brain's primary immune cells, can aid in preventing excessive activation and the release of detrimental inflammatory mediators.

The emerging connection between the gut-brain axis and LEO introduces a novel avenue for mitigating neuroinflammation. Recent investigations suggest that LEO can modulate the gut microbiota composition, thereby influencing gut-brain communication and systemic inflammatory responses. A healthy gut microbiota produces metabolites capable of crossing the blood-brain barrier and modulating brain function, including inflammatory responses. Consequently, LEO's effects on the gut microbiota may contribute to its neuroprotective effects via indirect pathways. This gut-brain axis modulation by LEO represents a promising therapeutic strategy for neuropsychiatric disorders associated with gut microbiota dysfunction and systemic inflammation.

Moreover, the well-documented anxiolytic and antidepressant effects of LEO may indirectly contribute to the reduction of neuroinflammation. Stress and depression are frequently associated with heightened systemic and neuroinflammation. By alleviating stress and depression, LEO can help disrupt the inflammatory cycle and promote overall mental health. This mechanism involves modulating neurotransmitters such as serotonin and GABA, which are crucial in mood regulation and inflammatory responses. Thus, LEO's psychological effects complement its direct anti-inflammatory actions, providing a comprehensive therapeutic approach for neuropsychiatric disorders.

In summary, the burgeoning evidence indicates that LEO possesses substantial therapeutic potential in reducing neuroinflammation and protecting the brain from damage. Its anti- inflammatory, antioxidant, and neuroprotective effects, mediated by its complex chemical composition, render it a promising candidate for the development of novel therapies for neuropsychiatric disorders. The modulation of the gut-brain axis and its psychological effects further reinforce LEO's therapeutic potential in the context of neuroinflammation and mental health. Further research is imperative to fully elucidate LEO's mechanisms of action and to explore its clinical potential in diverse neuropsychiatric conditions.

Moreover, Richard de Albuquerque Felizola Romeral et al. (2024) emphasize the potential applications of LEO in integrative medicine, particularly in psychiatric settings. The use of LEO in aromatherapy interventions has been associated with reduced symptoms of generalized anxiety disorder (GAD) and major depressive disorder (MDD). The ability of LEO to act on both the psychological and physiological dimensions of stress-related conditions underscores its potential as an adjunct therapy alongside conventional pharmacological treatments.

Finally, the role of LEO in managing stress and neuroinflammation represents an evolving field of research with promising implications for holistic health approaches. As noted by Fernandes et al. (2021), future studies should aim to refine the understanding of LEO's dose-response relationships, optimal delivery methods, and long-term effects on neuropsychiatric health Malhotra et al. (2024). Given the growing interest in natural therapeutics, LEO stands out as a viable option for individuals seeking alternative solutions to stress management and neuroinflammation-related conditions. With continued research and clinical validation, LEO could emerge as a mainstream complementary therapy in mental health care.

Lavender (Lavandula spp.) essential oil (LEO) has garnered significant attention for its diverse therapeutic applications, particularly in stress management and neuroinflammation. Hedayati et al. (2025) highlight the increasing demand for sustainable extraction methods to meet this growing interest, emphasizing the need for a "greener future" in LEO production. Traditional extraction techniques often rely on energy-intensive processes and environmentally harmful solvents. Therefore, innovations such as microwave-assisted extraction, supercritical fluid extraction, and ultrasound-assisted extraction are being explored to minimize environmental impact and enhance yield and quality. These methods align with the broader trend towards sustainable practices in the food and pharmaceutical industries, ensuring the long-term availability of this valuable resource.

The efficacy of LEO in mitigating stress and neuroinflammation is supported by its complex chemical composition, which includes linalool and linalyl acetate as primary constituents. From an immunopsychiatric perspective, LEO's ability to modulate the hypothalamic-pituitary- adrenal (HPA) axis and influence neurotransmitter systems plays a crucial role in its stress- reducing effects. Furthermore, its anti-inflammatory properties contribute to the management of neuroinflammation, which is implicated in various mental health disorders. This aligns with findings that essential oils can modulate mood and stress responses. For instance, the inhalation of citrus essential oils has shown promise in relieving exercise-induced fatigue, suggesting a broader application of aromatherapy in stress management (Tian et al. (2022).

Beyond single-oil applications, synergistic effects can be achieved through the formulation of essential oil blends. Awaluddin et al. (2023) demonstrated the potential of a reed diffuser combining cinnamon (Cinnamomomum verum) and citronella (Cymbopogon nardus) essential oils as an anti-stress aromatherapy. This study underscores the importance of carefully selecting and blending essential oils to maximize their therapeutic benefits. The combination of cinnamon and citronella, known for their calming and invigorating properties, respectively, offers a balanced approach to stress reduction. This formulation shows how combining multiple oils may provide a more comprehensive benefit than a single oil.

The impact of essential oils on mental health extends beyond stress reduction to the management of depression. Dobrek & Głowacka (2023) provide a narrative review of phytopharmacotherapy for depression, highlighting the potential of various plant-derived compounds, including essential oils, in alleviating depressive symptoms. LEO, with its anxiolytic and antidepressant properties, is a

promising candidate for adjunctive therapy in depression management. This review underscores the growing interest in natural remedies for mental health disorders, reflecting a shift towards holistic approaches that integrate conventional and complementary therapies.

The advancements in sustainable extraction, coupled with a deeper understanding of LEO's therapeutic mechanisms, pave the way for its broader application in stress management and neuroinflammation. The development of innovative formulations, such as the cinnamon and citronella reed diffuser, demonstrates the potential for synergistic effects in aromatherapy. Future research should focus on clinical trials to validate the efficacy of LEO and other essential oils in diverse populations and to explore optimal delivery methods. This would include detailed investigations into the immunopsychiatric pathways influenced by LEO, as well as the long-term effects of its use.

Lavender essential oil (LEO) continues to be a subject of intense scientific scrutiny, particularly regarding its efficacy in managing stress and neuroinflammation. The pursuit of sustainable extraction methods, as highlighted by Hedayati et al. (2025), is crucial for meeting the growing demand for LEO. This emphasis on "greener" techniques aligns with a broader trend towards utilizing natural resources responsibly. Concurrently, the quality of LEO, influenced by cultivation practices and extraction processes, plays a vital role in its therapeutic potential. Crisan et al. (2023) emphasize the current trends in Lavender (Lavandula angustifolia Mill.) crops and products, focusing on essential oil quality, which directly impacts its effectiveness.

The neuroprotective potential of LEO is increasingly recognized, with studies exploring its mechanisms of action in neurodegenerative disorders. Angeloni et al. (2023) discuss the potential neuroprotective activity of agrifood by-products, including essential oils, highlighting their antioxidant properties. This aligns with the understanding that LEO's ability to modulate oxidative stress and inflammation contributes to its therapeutic effects. From an immunopsychiatric perspective, LEO's capacity to influence the HPA axis and neurotransmitter systems is pivotal in its stress-reducing effects. Algristian, Bintarti, Baroroh, et al. (2022)have shown the protective effect of lavender essential oils on depression and multi-organ stress. This indicates that LEO's benefits extend beyond psychological well-being to encompass physiological stress responses.

The cognitive enhancing effects of LEO have also been explored, with Malloggi et al. (2022) conducting a systematic review of lavender aromatherapy, focusing on essential oil quality, administration methods, and cognitive impacts. This review underscores the importance of standardized administration protocols to maximize LEO's cognitive benefits. The method of administration, whether through inhalation or topical application, can significantly influence the bioavailability and efficacy of LEO's bioactive compounds. These findings emphasize the need for careful consideration of both oil quality and delivery methods in clinical applications.

Furthermore, the influence of LEO on gut-brain interactions is emerging as a significant area of research. Li et al. (2024) revealed that lavender essential oil alleviates depressive-like behavior in

alcohol-withdrawn rats, providing insights from gut metabolites and hippocampal transcriptome analysis. This study highlights the complex interplay between the gut microbiota, brain function, and mental health, suggesting that LEO may exert its antidepressant effects through multiple pathways. This emphasizes the importance of understanding the gut-brain axis in the context of LEO's therapeutic mechanisms.

The convergence of sustainable extraction practices, rigorous quality control, and a deeper understanding of LEO's multifaceted mechanisms of action is paving the way for its broader clinical application. Future research should focus on large-scale clinical trials to validate LEO's efficacy in diverse populations and to explore optimal delivery methods. Additionally, investigations into the long-term effects of LEO use and its potential interactions with other therapies are warranted.

Neuroinflammation, a contributing factor to various mental health conditions, is another critical area where LEO demonstrates therapeutic potential. The oil's anti-inflammatory properties, attributed to its complex chemical composition, including linalool and linalyl acetate, help mitigate this inflammation. Research indicates that these compounds possess antioxidant activities, further contributing to their neuroprotective effects. By reducing neuroinflammation, LEO may play a role in preventing or slowing neurodegenerative processes, offering a promising avenue for managing conditions associated with chronic inflammation in the brain. The connection between the gut brain axis, and LEO, is also showing to be a possible way to reduce neuroinflammation.

The immunopsychiatric perspective emphasizes the interconnectedness of the immune and nervous systems. LEO's ability to influence both systems highlights its relevance in this field. By modulating inflammatory responses and neurotransmitter activity, LEO addresses the holistic nature of mental and physical well-being. This dual action underscores its potential as a natural therapeutic agent that can address the root causes of stress and neuroinflammation, rather than merely treating symptoms. Further research is needed to fully elucidate the specific pathways and mechanisms through which LEO exerts its immunopsychiatric effects.

Although many studies show promising results regarding the therapeutic potential of LEO, there are still several methodological limitations that should be taken into account when interpreting the findings. For instance, some clinical trials used small sample sizes, which can reduce the reliability and generalizability of the results. In addition, many studies did not include placebo control groups, making it difficult to determine whether the observed effects were truly due to LEO or simply a placebo response especially since aromatherapy studies are prone to subjective bias. The duration of most interventions was also relatively short, typically lasting only a few days or weeks, which limits our understanding of LEO's long-term safety and effectiveness. Differences in the method of LEO administration such as inhalation, oral intake, or topical use and variations in oil quality due to different extraction techniques further contribute to inconsistent findings. Moreover, only a few studies reported potential side effects or examined how LEO interacts with other medications, such as SSRIs or benzodiazepines. Lastly, the possibility of publication bias, where studies with positive outcomes are more likely to be published, may also affect the

overall interpretation of the evidence. These limitations highlight the importance of conducting more rigorous, standardized, and long-term research to better establish the role of LEO in managing stress and neuroinflammation.

CONCLUSION

In conclusion, lavender essential oil (LEO) presents a compelling natural therapeutic agent for managing stress and neuroinflammation within the framework of immunopsychiatry. Its capacity to modulate the hypothalamic-pituitary-adrenal (HPA) axis, reduce neuroinflammation through antioxidant and anti-inflammatory mechanisms, and influence the complex interplay between the immune and nervous systems underscores its potential. The emerging evidence, both preclinical and clinical, suggests that LEO can offer a holistic approach to addressing the interconnectedness of mental and physical well-being. By targeting fundamental pathways involved in stress and inflammation, LEO provides a valuable tool for promoting mental health and potentially mitigating the progression of neurodegenerative conditions.

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